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(71) Applicant (*for all designated States except US*): **GRAPH-TECH INC.** [US/US]; 11709 Madison Avenue, Lakewood, OH 44107 (US).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **WEBER, Thomas, William** [US/US]; 6034 Brookside Drive, Cleveland, OH 44114 (US). **PAVLISIN, James, Joseph** [US/US]; 3452 West 135th Street, Cleveland, OH 44111 (US). **TZENG, Jing-Wen** [—/US]; 3622 Lennox Circle, Brunswick, OH 44212 (US). **MERCURI, Robert, Angelo** [US/US]; 1007 East Decker Drive, Seven Hills, OH 44131 (US). **QUANDT, Herbert, Clayton** [US/US]; 16104 Lake Avenue, Lakewood, OH 44107 (US).

(74) Agent: **CARTIGLIA, James, R.**; UCAR International Inc., 3102 West End Avenue, Suite 1100, Nashville, TN 37203 (US).

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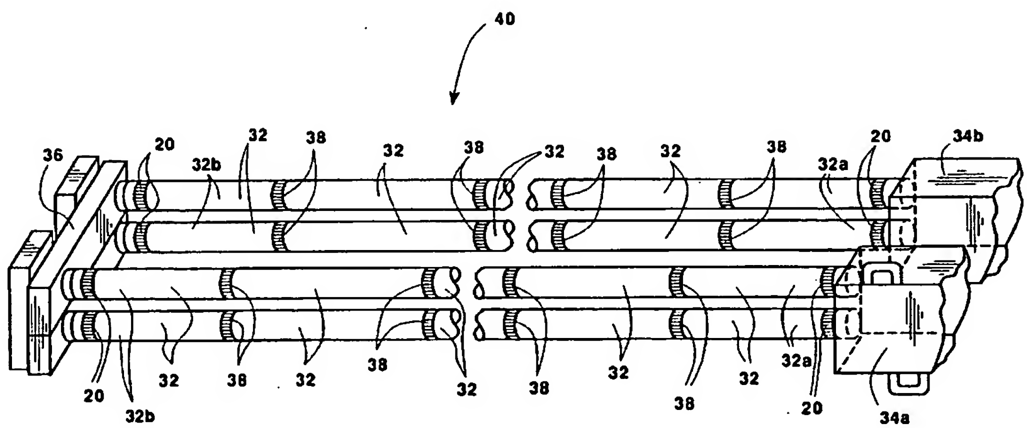
(54) Title: SYSTEM FOR REDUCTION IN TEMPERATURE VARIATION DURING LENGTHWISE GRAPHITIZATION OF CARBON BODIES



(57) Abstract: A method for heat treating carbon products comprises providing a pair of electrodes (34a, 34b), providing a carbon body (32) in electrical contact between the electrodes (34a, 34b), and inserting a joint (20) between at least one of the electrodes (34a, 34b) and the carbon body (32). The joint (20) has a plurality of layers of a low electrical resistivity material; and a plurality of layers of a high electrical resistivity material. The layers of low and high electrical resistivity materials are in alternating relationship and of a thickness sufficient such that an electric current passing through the layers may generate a desired amount of heat which flows to the carbon body (32). The method includes passing an electric current through the electrode (34a or 34b), joint (20) and carbon body (32) and generating a desired amount of heat in the joint (20) with the electric current to heat a portion of the carbon body (32) adjacent the joint (20) to a graphitizing temperature. Preferably, the layer of low electrical resistivity material comprises graphite, more preferably, flexible graphite foil having a density less than about 0.5 g/cc. Preferably, the layer of high electrical resistivity material comprises a cellulose-based material or graphite foil having a density greater than about 0.5 g/cc.

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SYSTEM FOR REDUCTION IN TEMPERATURE VARIATION DURING LENGTHWISE GRAPHITIZATION OF CARBON BODIES

Description

Technical Field

This invention relates to the graphitization of carbon bodies by passing electric current through the bodies, and in particular to a joint for use in controlling heat loss in the carbon bodies.

Background of the Invention

Lengthwise graphitization (LWG) of carbon bodies to form graphite electrodes for use in electric arc scrap melting furnaces is described in U.S. Patent 5,631,919. In this process, carbon bodies are placed in end-to-end contact forming an electrically conductive column. The carbon bodies are supported by and covered with granular carbon for insulation; and electrical current is passed through the column of carbon bodies heating them to graphitization temperature, e.g., 2500°C -3500°C by the Joule effect. It is the practice to place a low electrical resistivity material at the space between the ends of the carbon bodies to assist in the current flow from piece-to-piece as the current is passed through the column. The material placed between the pieces typically is low electrical resistivity graphite particles, with or without a binder, or graphite felt. The material making up the piece-to-piece connection is sometimes referred to as a "joint".

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To transfer the electrical current from a power source to the column of carbon bodies, a graphite block is machined to shape to accommodate connections to the power source or rectiformer. This graphite piece or head electrode is placed at the end of the furnace. An example of the location of a type of head electrode can be seen in Figure 1 of U.S. Patent 1,029,121 at G and G^3 (referred to in the specification as terminals). The same drawing in the '121 patent also shows the joint material at F referred to in the specification, page 1, lines 53-54, as a "... packing F of graphite forming a good electrical connection between them." The connection between the carbon bodies is further described on page 2, lines 1-28 wherein the "joint" nomenclature is used to describe the method of preparing the connection using granular material.

To accommodate the difference in length of the carbon bodies in a LWG furnace, smaller pieces of graphite have been inserted at the ends of the column of carbon bodies. These graphite pieces form part of the column and are referred to as spacers. When the power is applied to the LWG furnace, very large electrical currents (50,000-150,000 A) heat the carbon bodies by the Joule effect ($I^2 R$) to temperatures up to 3500°C, sufficient to convert the carbon to graphite. This is typically accomplished in 8-18 hours, at which time the electrical power is discontinued, and the graphitized carbon bodies begin to cool.

The carbon bodies that are closest to the head electrodes are subject to higher heat losses by conduction through the ends than the carbon bodies in the internal locations of the furnace. These higher conductive losses are due to the use of graphite - which is a good conductor of heat - for the head electrodes that make the connection between the power source and the column of carbon bodies. Water cooling is used for the graphite head electrodes. The end of the head electrodes containing the water cooling tubes is connected to the rectiformer by means of copper bars. During the heating and cooling part of the furnace cycle, this end of the electrode must receive sufficient water flow to prevent the copper tubing and copper bars from overheating and even possible melting. Typically, this end of the head electrodes can reach temperatures in the range of 100-200°C. Similarly, the electrical connection at the opposite end of the furnace, called the

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crossover, is graphite and also imparts conductive heat losses; causing the end of the carbon body next to the graphite crossover to be significantly cooler than the internally located carbon bodies during firing and at off-fire.

It has been found that the lower temperature during heating and at off-fire at the ends of the carbon bodies next to the head electrodes and crossover is undesirable. The carbon bodies located in these positions do not achieve a uniform degree of graphitization throughout the entire body, and this non-uniformity results in measurable variation in the electrical and thermal characteristics of the graphite. This can ultimately influence the performance of the products made from the graphite.

Summary of the Invention

Bearing in mind the problems and deficiencies of the prior art, it is therefore an object of the present invention to provide a system by which more uniform graphitization can be achieved when graphitizing carbon bodies using the Joule effect.

It is another object of the present invention to provide an improved system for uniformly graphitizing carbon bodies to form graphite electrodes.

A further object of the invention is to provide a system which reduces heat loss at the ends of carbon bodies in a LWG furnace.

It is yet another object of the present invention to provide an improved joint for use in a LWG furnace.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The above and other objects, which will be apparent to those skilled in the art, are achieved in the present invention which relates in a first aspect to a joint for heat treating

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carbon products comprising at least one layer of a low electrical resistivity material and at least one layer of a high electrical resistivity material. The layers of low and high resistivity materials are arranged in alternating relationship and are of a size sufficient to locate between carbon bodies or between a carbon body and an electrode such that an electric current may pass through the layers, the layers being of thickness sufficient to generate a desired amount of heat when the electric current passes through the layers.

In another aspect, the present invention provides a system for heat treating carbon products comprising a pair of electrodes, a carbon body in electrical contact between the electrodes and a joint between at least one of the electrodes and the carbon body. The joint has at least one layer of a low electrical resistivity material and at least one layer of a high electrical resistivity material. The layers of low and high resistivity materials are in alternating relationship and of a thickness sufficient such that an electric current passing through the layers may generate a desired amount of heat which flows to the carbon body.

In a further aspect, the present invention provides a system for heat treating carbon products comprising a first carbon body, a second carbon body and a joint between the first and second carbon bodies. The joint has at least one layer of a low electrical resistivity material; and at least one layer of a high electrical resistivity material. The layers of low and high resistivity materials are in alternating relationship and of a thickness sufficient such that an electric current passing through the layers may generate a desired amount of heat which flows to the carbon bodies.

In yet another aspect, the present invention provides a method for heat treating carbon products comprising providing a pair of electrodes, providing a carbon body in electrical contact between the electrodes, and inserting a joint between at least one of the electrodes and the carbon body. The joint has at least one layer of a low electrical resistivity material; and at least one layer of a high electrical resistivity material. The layers of low and high electrical resistivity materials are in alternating relationship and of a thickness sufficient such that an electric current passing through the layers may generate

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a desired amount of heat which flows to the carbon body. The method then includes passing an electric current through the electrode, joint and carbon body and generating a desired amount of heat in the joint with the electric current to heat a portion of the carbon body adjacent the joint to a desired temperature, preferably graphitizing temperature.

Preferably, the layer of low electrical resistivity material comprises graphite, more preferably, flexible graphite foil having a density less than about 0.5g/cc. Preferably, the layer of high electrical resistivity material comprises a cellulose-based material or graphite foil having a density greater than about 0.5g/cc. The joint may be disc-shaped. Also, the layer of high electrical resistivity material may have openings therein to increase passage of electric current through the at least one layer of low electrical resistivity material. The thickness of the layer of high electrical resistivity material may preferably range from about 0.1 to 1.0mm and the thickness of the layer of low electrical resistivity material may preferably range from about 1 to 50mm. The joint may include a plurality of layers of the high electrical resistivity material and a plurality of layers of the low electrical resistivity material, with the high and low electrical resistivity layers being in alternating disposition.

Brief Description of the Drawings

The features of the invention believed to be novel and the elements characteristic of the invention are set forth with particularity in the appended claims. The figures are for illustration purposes only and are not drawn to scale. The invention itself, however, both as to organization and method of operation, may best be understood by reference to the detailed description which follows taken in conjunction with the accompanying drawings in which:

Fig. 1 is an exploded elevational view of one example of the LWG furnace joint of the present invention.

Fig. 2 is an elevational view of the assembled LWG furnace joint of Fig. 1.

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Fig. 3 is a top plan view of an example of the high electrical resistivity layer used in the LWG furnace joint of Fig. 2.

Fig. 4 is a perspective view of a LWG furnace utilizing the preferred LWG furnace joint of the present invention.

Fig. 5 is a graphical representation of the relationship of temperature versus time comparing the joint made in accordance with the present invention with the prior art joint.

Fig. 6 is a graphical representation of the relationship of specific resistance versus time comparing the joint made in accordance with the present invention with the prior art joint.

Detailed Description of the Preferred Embodiments

In describing embodiments of the present invention, reference will be made herein to Figs. 1-6 of the drawings in which like numerals refer to like features of the invention. Features of the invention are not necessarily shown to scale in the drawings.

It has been determined that the portions of the carbon pieces located adjacent to the head electrodes and crossovers in a longitudinal or lengthwise graphitizing (LWG) furnace may be subject to lower conductive heat losses than those of the prior art by using a novel joint at these locations. In its most preferred embodiment, the construction of this invention utilizes alternating layers of flexible graphite and paper which can be varied to increase the Joule effect or I^2R heating. The increased heat generated by this invention has been found to offset the higher conductive heat losses; resulting in more uniform temperature, both during the heating cycle and at off-fire.

The subject invention preferably has alternating construction of layers of a material of relatively low electrical and thermal resistivity (or specific resistance), such as

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flexible graphite, and a material of relatively high electrical and thermal resistivity (or specific resistance), such as paper or other cellulose-based material, that can be used as a packing or joint at the critical head and crossover positions of an LWG furnace in place of the conventional graphite particles to overcome higher heat losses at these locations. The terms low resistance and high resistance are, of course, relative, and are used in their ordinary meaning in the art. An example of low electrical resistance useful in the present invention is an electrical resistivity of about 1 to 1,000 micro-ohm-meters, and an example of high electrical resistance useful in the present invention is an electrical resistivity higher than about 10,000 micro-ohm-meters. This construction helps to reduce the temperature non-uniformity of the carbon bodies during graphitization. The preferred article is constructed so that its overall specific resistance is sufficient to produce the necessary I^2R heat during firing to overcome the conductive heat losses from these end positions.

An example of this invention is shown in Figs. 1, 2 and 3. Layers of low electrical and thermal resistivity GRAFOIL® flexible graphite 22 (available from UCAR Graph-Tech Inc. of Lakewood, Ohio) and high electrical and thermal resisitvity Kraft paper 24 were cut in a circular or disk shape to form a packing or joint 20. The joint layers may be made in other configurations to match the cross section of the electrode column to which the joint is to be mated. The multiple graphite and paper layers were alternated across the thickness (Fig. 1), adhesively bonded and compressed to form the final product (Fig. 2). Preferably, the low resistivity graphite layers are exposed at the top 26 and bottom 28 surfaces of the joint 20. More preferably, as shown in Fig. 3, 6mm or other suitable diameter holes 30 are punched in each layer of paper 24 to provide some physical contact between the alternating low electrical resistivity layers 22 to enable current to flow more easily between these layers at furnace start-up.

Other exemplary materials which may be used for the low electrical resistivity layer 22 are flexible graphite, monolithic graphite and graphite foams. Exemplary materials which may be used for the high electrical resistivity layer 24 are high density

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graphite foils, carbon paper, cloth and cellulose-based materials such as cardboard. It has been found that in some instances low density GRAFOIL® flexible graphite (e.g., a density of less than about 0.5g/cc, preferably less than about 0.25g/cc) has lower electrical resistivity than higher density flexible graphite (e.g., a density of at least about 0.5g/cc, and preferably at least about 1.0 g/cc), as measured in a direction normal to the plane of the layer. As such, low density flexible graphite layers can be employed as low conductivity layers 22 while higher density flexible graphite layers can be employed as high conductivity layers 24 in Figs. 1-3.

The layers of low electrical resistivity and high electrical resistivity materials can be varied in number, thickness and density to achieve the desired electrical resistivity (or conductivity) through the thickness of the joint, which in turn generates the desired heat by the Joule effect when current flows through the thickness. While each of the low and high resistivity layers are shown extending completely across the width of the joint (except for paper holes 30), such layers may extend only partially across the joint, depending on the desired resistance across the joint thickness. By experimentation, it has been discovered that flexible graphite density in the density range of about 0.3 g/cc and thickness of about 2mm along with alternating layers of about 0.15 mm Kraft paper produce the desired electrical and thermal properties. More broadly, the flexible graphite low resistivity layer may be employed in a thickness range of about 1mm to about 50mm, and a paper-based high resistivity layer may be employed in a thickness range of about 0.1mm to about 1mm.

Fig. 4 depicts the arrangement of carbon bodies and the joint of the present invention in a LWG furnace 40. A plurality of cylindrical carbon bodies 32, to be made into graphite electrodes, are connected at their ends to form two pairs of parallel extended lengths. Water-cooled, graphite head electrodes 34a, 34b provide electrical power connection to the carbon lengths at one end of the furnace. Similarly, the two lengths of carbon bodies are electrically connected at the opposite end of the furnace by graphite crossover 36. Graphite spacers 38 are inserted at the ends of the individual carbon bodies

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32 to accommodate any difference in accumulated length of the carbon bodies. A granular thermal insulation material (not shown) normally covers the carbon bodies during heating.

To reduce heat loss by conduction, joints 20 made in accordance with the present invention are disposed between head electrodes 34a, b and end portions 32a of the carbon bodies closest to the head electrodes. Similarly, joints 20 are provided between crossover electrical connection 36 and the ends 32b of the carbon bodies adjacent to the crossover. When the power is applied to the LWG furnace and the typical 50,000-150,000 A electrical currents flows through the carbon bodies, the Joule effect will cause the joints 20 to be heated to a greater degree than if they were made of the conventional prior art graphite. This higher heating effect offsets and overcomes the heat sinking effect of the head electrodes 34a, 34b and crossover 36 to the carbon body ends 32a, 32b and causes graphitization within the carbon bodies to be more uniform, particularly at the carbon body ends. This results in less variation in the electrical and thermal characteristics of the graphite in bodies 32, and improves the performance of the products made from the graphite, particularly when the products are graphite electrodes.

Actual furnace trials were conducted to compare the results of the invention to the normal practice of using graphite particles between the pieces. The temperature versus time relationship of different types of joints during graphitization in a LWG furnace (of the type shown in Fig. 4) is compared in Fig. 5. The graph shows that the present invention joint results in higher temperatures than the prior art graphite particle joint. The invention joint also had a higher temperature than the mid-length carbon body position. The higher temperatures make the invention useful in a LWG furnace in overcoming the heat losses when placed in the column at the head and crossover positions described earlier.

The difference in specific resistance between the prior art graphite particle joint and the invention joint during firing of carbon bodies is shown in the graph in Fig. 6. In

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this graph, the overall specific resistance of the material between the carbon bodies was measured using identical equipment and methods during the same firing in a LWG furnace as in Fig. 5. The plot shows that the invention joint has a higher specific resistance during the initial stages of firing than the prior art joint made from graphite particles. For reference, the specific resistance of a carbon body electrode length during firing is also shown.

Thus, the present invention achieves the objects described above to provide an improved joint for use in a LWG furnace. The system of the present invention reduces heat sink loss at the ends of carbon bodies in a LWG furnace. Employing the joint of the present invention results in more uniform graphitization can be achieved when graphitizing carbon bodies using the Joule effect, particularly when heat treating carbon bodies to form graphite electrodes.

While the present invention has been particularly described, in conjunction with a specific preferred embodiment, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. It is therefore contemplated that the appended claims will embrace any such alternatives, modifications and variations as falling within the true scope and spirit of the present invention.

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What is claimed is

1. A joint for heat treating carbon products comprising:
at least one layer of a low electrical resistivity material; and
at least one layer of a high electrical resistivity material,
said layers of low and high resistivity materials being in alternating relationship and of a size sufficient to locate between carbon bodies or between a carbon body and an electrode such that an electric current may pass through said layers, said layers being of thickness sufficient to generate a desired amount of heat when said electric current passes through said layers.

2. The joint of claim 1 wherein said at least one layer of low electrical resistivity material is also of low thermal resistivity.

3. The joint of claim 1 wherein said at least one layer of low electrical resistivity material comprises graphite.

4. The joint of claim 1 wherein said at least one layer of low electrical resistivity material comprises flexible graphite foil.

5. The joint of claim 1 wherein said at least one layer of low electrical resistivity material comprises graphite foil having a density less than about 0.5g/cc.

6. The joint of claim 1 wherein said at least one layer of high electrical resistivity material is also of high thermal resistivity.

7. The joint of claim 1 wherein said at least one layer of high electrical resistivity material comprises a cellulose-based material.

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8. The joint of claim 1 wherein said at least one layer of high electrical resistivity material comprises graphite foil having a density greater than about 0.5g/cc.

9. The joint of claim 1 wherein said joint is disc-shaped.

10. The joint of claim 1 wherein said at least one layer of high electrical resistivity material has openings therein to increase passage of electric current through said at least one layer of low electrical resistivity material.

11. The joint of claim 1 wherein said at least one layer of high electrical resistivity material has a thickness of about 0.1 to 1.0mm and said at least one layer of low electrical resistivity material has a thickness of about 1 to 50mm.

12. The joint of claim 1 including a plurality of layers of said high electrical resistivity material and a plurality of layers of said low electrical resistivity material, the high and low electrical resistivity layers being in alternating disposition.

13. The joint of claim 1 including a plurality of layers of said high electrical resistivity material comprising flexible graphite and a plurality of layers of said low electrical resistivity material comprising a cellulose-based material, the high and low electrical resistivity layers being in alternating disposition.

14. The joint of claim 1 including a plurality of layers of said high electrical resistivity material comprising graphite foil having a density less than about 0.5g/cc and a plurality of layers of said low electrical resistivity material comprising graphite foil having a density greater than about 0.5g/cc, the high and low electrical resistivity layers being in alternating disposition.

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15. A system for heat treating carbon products comprising:

a pair of electrodes;

a carbon body in electrical contact between said electrodes; and

a joint between at least one of said electrodes and said carbon body, said joint having at least one layer of a low electrical resistivity material; and at least one layer of a high electrical resistivity material, said layers of low and high resistivity materials being in alternating relationship and of a thickness sufficient such that an electric current passing through said layers may generate a desired amount of heat which flows to said carbon body.

16. The system of claim 15 wherein said at least one layer of low electrical resistivity material is also of low thermal resistivity.

17. The system of claim 15 wherein said at least one layer of low electrical resistivity material comprises graphite.

18. The system of claim 15 wherein said at least one layer of low electrical resistivity material comprises flexible graphite foil.

19. The system of claim 15 wherein said at least one layer of low electrical resistivity material comprises graphite foil having a density less than about 0.5g/cc.

20. The system of claim 15 wherein said at least one layer of high electrical resistivity material is also of high thermal resistivity.

21. The system of claim 15 wherein said at least one layer of high electrical resistivity material comprises a cellulose-based material.

22. The system of claim 15 wherein said at least one layer of high electrical resistivity material comprises graphite foil having a density greater than about 0.5g/cc.

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23. The system of claim 15 wherein said joint is disc-shaped.

24. The system of claim 15 wherein said at least one layer of high electrical resistivity material has openings therein to increase passage of electric current through said at least one layer of low electrical resistivity material.

25. The system of claim 15 wherein said at least one layer of high electrical resistivity material has a thickness of about 0.1 to 1.0mm and said at least one layer of low electrical resistivity material has a thickness of about 1 to 50mm.

26. The system of claim 15 wherein the joint includes a plurality of layers of said high electrical resistivity material and a plurality of layers of said low electrical resistivity material, the high and low electrical resistivity layers being in alternating disposition.

27. The system of claim 15 wherein the joint includes a plurality of layers of said high electrical resistivity material comprising flexible graphite and a plurality of layers of said low electrical resistivity material comprising a cellulose-based material, the high and low electrical resistivity layers being in alternating disposition.

28. The system of claim 15 wherein the joint includes a plurality of layers of said high electrical resistivity material comprising graphite foil having a density less than about 0.5g/cc and a plurality of layers of said low electrical resistivity material comprising graphite foil having a density greater than about 0.5g/cc, the high and low electrical resistivity layers being in alternating disposition.

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29. A system for heat treating carbon products comprising:

a first carbon body;

a second carbon body; and

a joint between said first and second carbon bodies, said joint having at least one layer of a low electrical resistivity material; and at least one layer of a high electrical resistivity material, said layers of low and high electrical resistivity materials being in alternating relationship and of a thickness sufficient such that an electric current passing through said layers may generate a desired amount of heat which flows to said carbon bodies.

30. The system of claim 29 wherein said at least one layer of low electrical resistivity material is also of low thermal resistivity.

31. The system of claim 29 wherein said at least one layer of low electrical resistivity material comprises graphite.

32. The system of claim 29 wherein said at least one layer of low electrical resistivity material comprises flexible graphite foil.

33. The system of claim 29 wherein said at least one layer of low electrical resistivity material comprises graphite foil having a density less than about 0.5g/cc.

34. The system of claim 29 wherein said at least one layer of high electrical resistivity material is also of high thermal resistivity.

35. The system of claim 29 wherein said at least one layer of high electrical resistivity material comprises a cellulose-based material.

36. The system of claim 29 wherein said at least one layer of high electrical resistivity material comprises graphite foil having a density greater than about 0.5g/cc.

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37. The system of claim 29 wherein said joint is disc-shaped.

38. The system of claim 29 wherein said at least one layer of high electrical resistivity material has openings therein to increase passage of electric current through said at least one layer of low electrical resistivity material.

39. The system of claim 29 wherein said at least one layer of high electrical resistivity material has a thickness of about 0.1 to 1.0mm and said at least one layer of low electrical resistivity material has a thickness of about 1 to 50mm.

40. The system of claim 29 wherein the joint includes a plurality of layers of said high electrical resistivity material and a plurality of layers of said low electrical resistivity material, the high and low electrical resistivity layers being in alternating disposition.

41. The system of claim 29 wherein the joint includes a plurality of layers of said high electrical resistivity material comprising flexible graphite and a plurality of layers of said low electrical resistivity material comprising a cellulose-based material, the high and low electrical resistivity layers being in alternating disposition.

42. The system of claim 29 wherein the joint includes a plurality of layers of said high electrical resistivity material comprising graphite foil having a density less than about 0.5g/cc and a plurality of layers of said low electrical resistivity material comprising graphite foil having a density greater than about 0.5g/cc, the high and low electrical resistivity layers being in alternating disposition.

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43. A method for heat treating carbon products comprising:
providing a pair of electrodes;
providing a carbon body in electrical contact between said electrodes;
inserting a joint between at least one of said electrodes and said carbon body, said joint having at least one layer of a low electrical resistivity material; and at least one layer of a high electrical resistivity material, said layers of low and high electrical resistivity materials being in alternating relationship and of a thickness sufficient such that an electric current passing through said layers may generate a desired amount of heat which flows to said carbon body;
passing an electric current through said electrode, joint and carbon body; and
generating a desired amount of heat in said joint with said electric current to heat a portion of said carbon body adjacent said joint to a desired temperature.

44. The method of claim 43 wherein sufficient heat is generated to graphitize at least a portion of said carbon body adjacent said joint.

45. The method of claim 43 wherein said step of inserting a joint comprises inserting a joint having a plurality of layers of said high electrical resistivity material and a plurality of layers of said low electrical resistivity material, the high and low electrical resistivity layers being in alternating disposition.

46. The method of claim 43 wherein said step of inserting a joint comprises inserting a joint having a plurality of layers of said high electrical resistivity material comprising flexible graphite and a plurality of layers of said low electrical resistivity material comprising a cellulose-based material, the high and low electrical resistivity layers being in alternating disposition.

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47. The method of claim 43 wherein said step of inserting a joint comprises inserting a joint having a plurality of layers of said high electrical resistivity material comprising graphite foil having a density less than about 0.5g/cc and a plurality of layers of said low electrical resistivity material comprising graphite foil having a density greater than about 0.5g/cc, the high and low electrical resistivity layers being in alternating disposition.

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Fig. 1

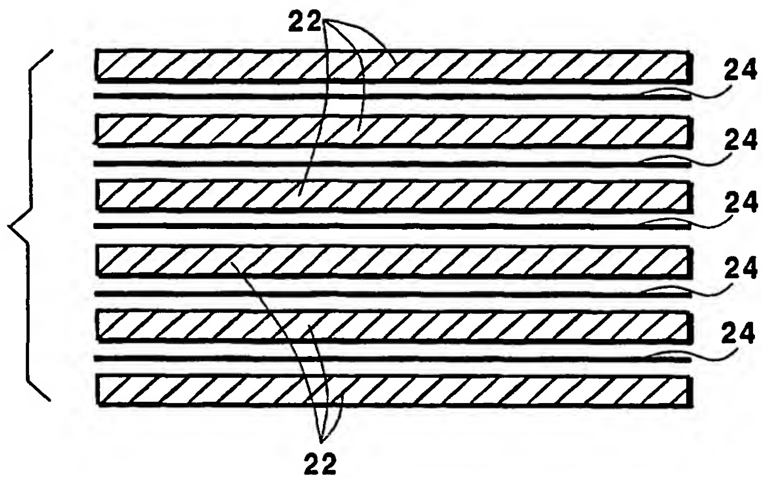


Fig. 2

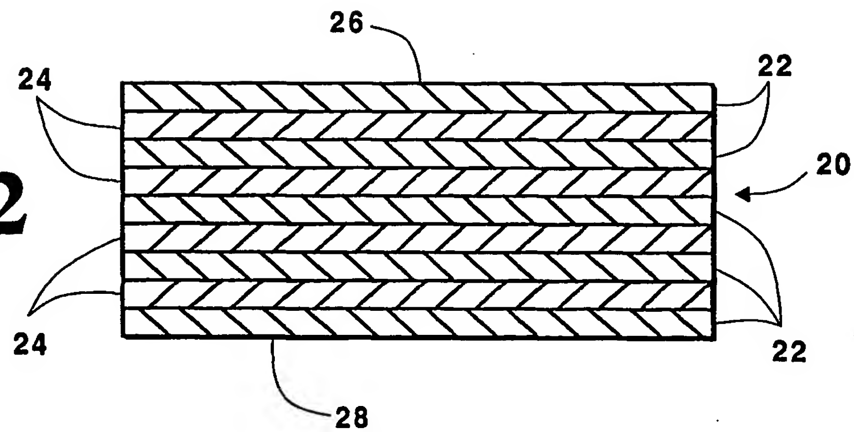
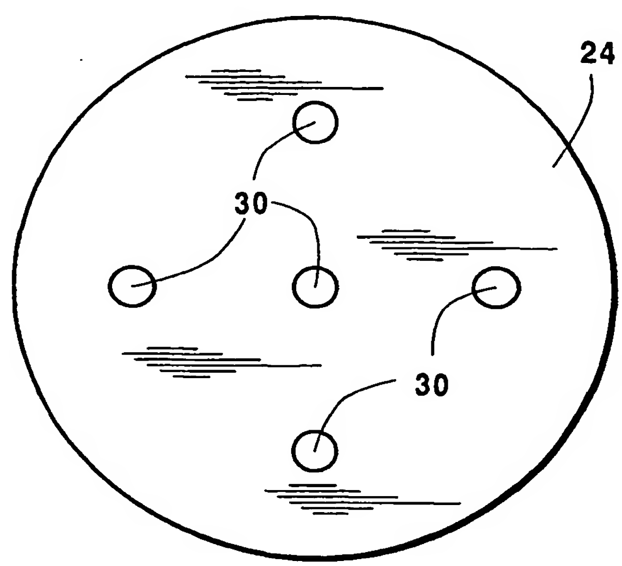


Fig. 3



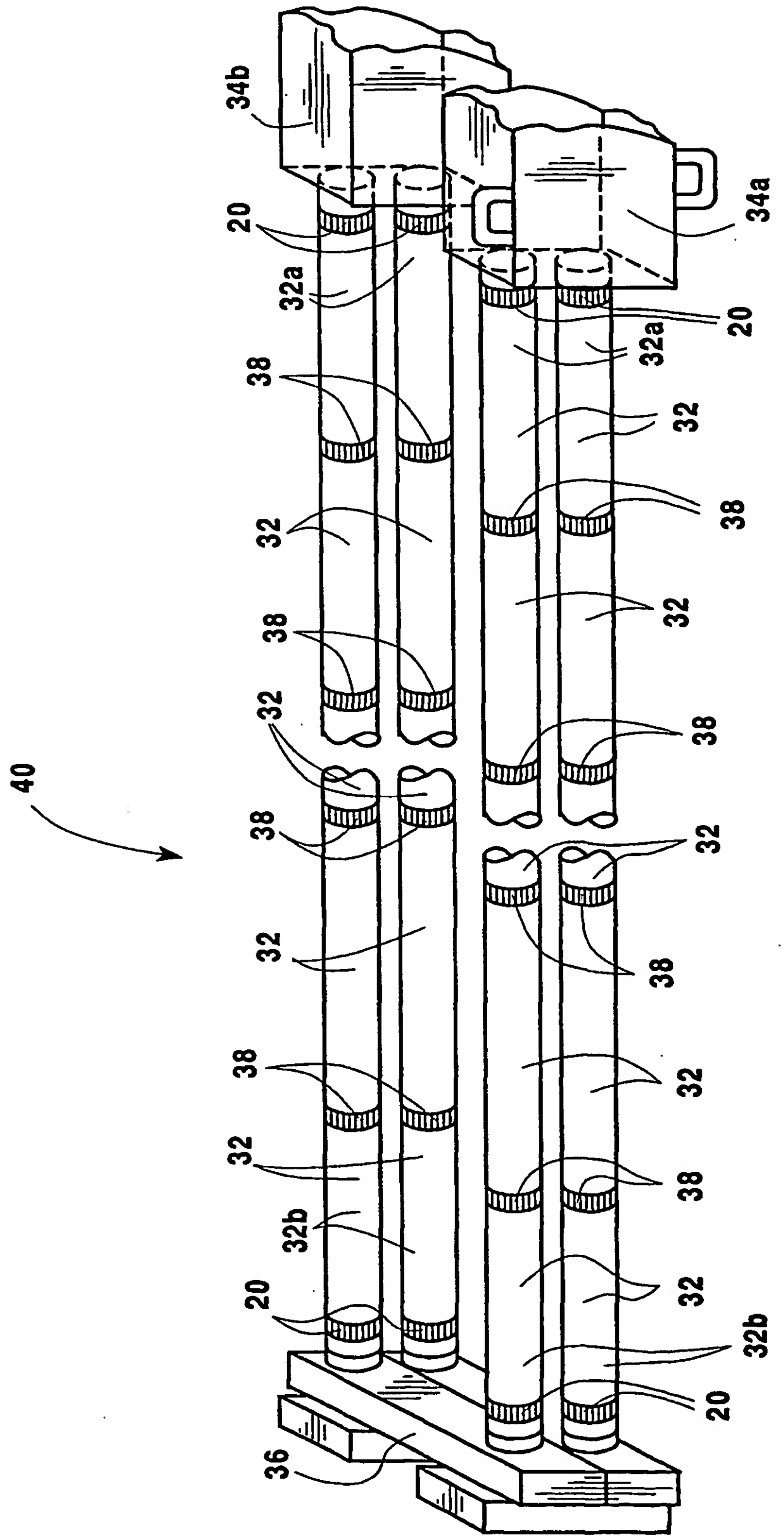


Fig. 4

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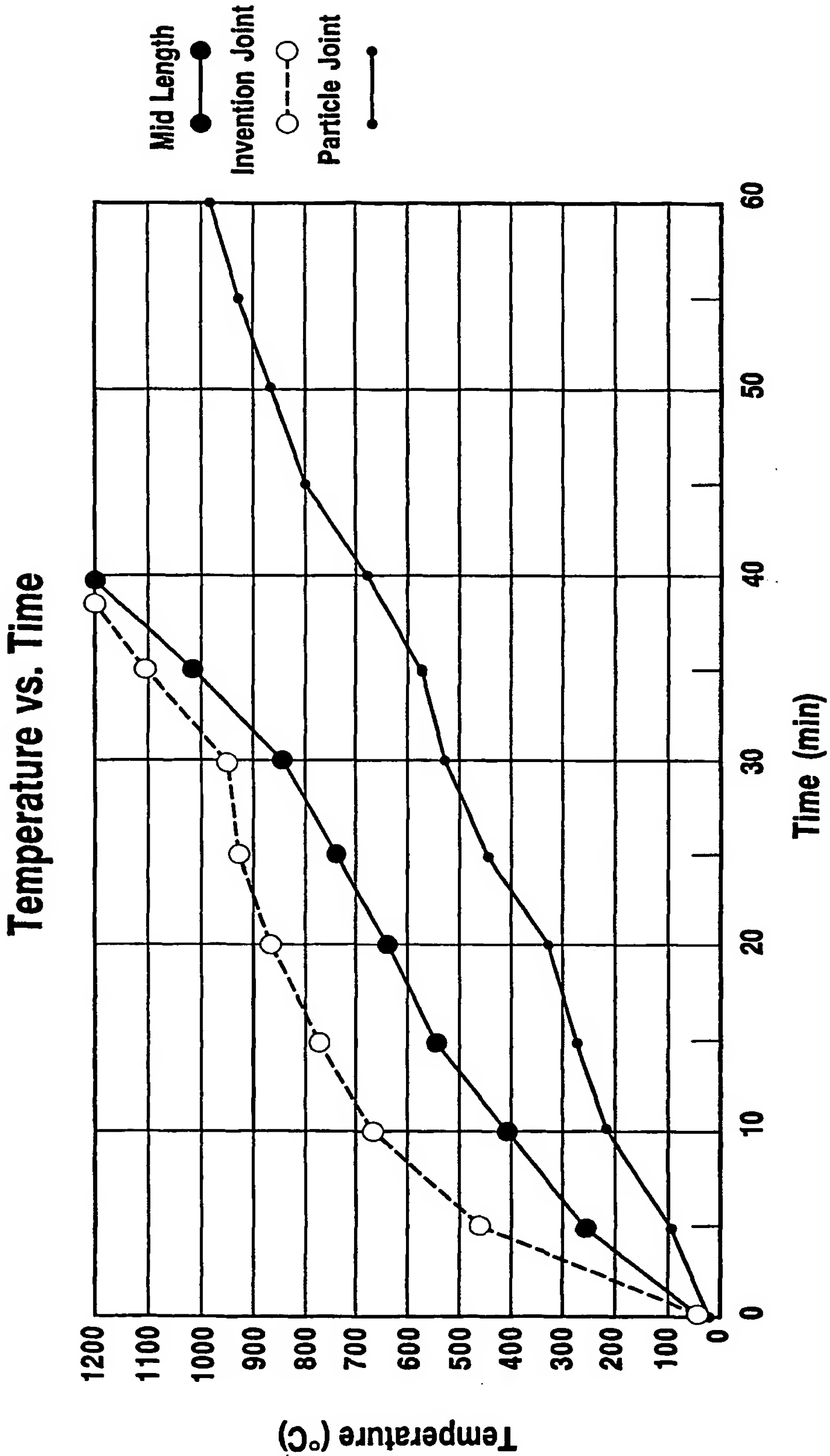
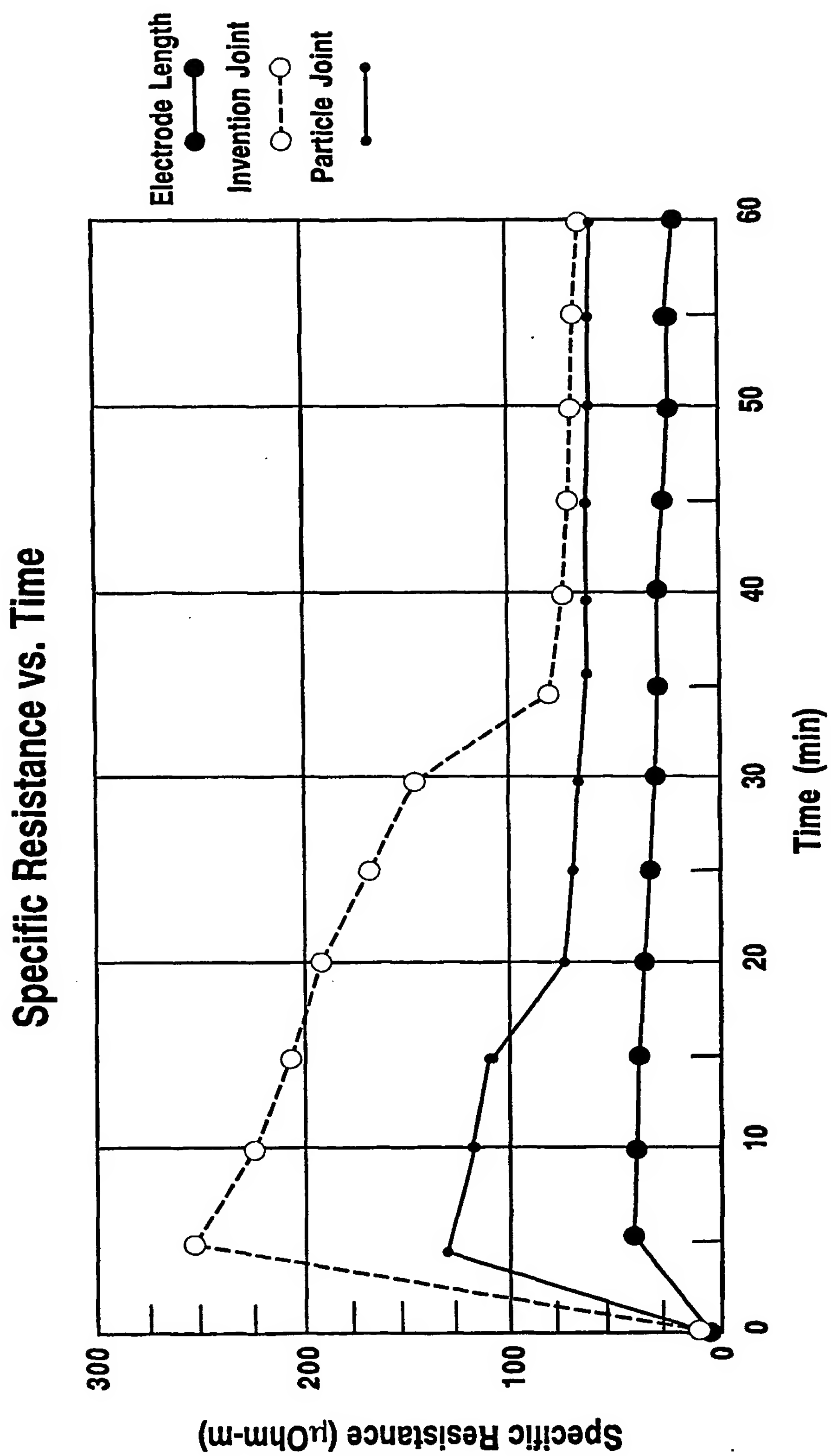
Fig. 5



BNSDOCID: <WO_________0178460A1_I_>

Fig. 6



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/09528

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H05B 7/06, 3/60
US CL :373/91

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 373/88, 89, 90-92, 109, 117, 120

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,631,919 A (INTERMILL ET AL) 20 MAY 1997, see the entire reference.	1-47.
A	US 5,854,807 A (BOISVERT ET AL) 29 DECEMBER 1998, see the entire reference.	1-47
A	US 5,117,439 A (DAGATA ET AL) 26 MAY 1992, see the entire reference.	1-47
A	US 2,728,109 A (BONNOT) 27 DECEMBER 1955, see the entire reference.	1-47
A	US 473,117 A (HEROULT) 19 APRIL 1892, see the entire reference.	1-47

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

26 JUNE 2000

Date of mailing of the international search report

12 OCT 2000

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
TU HOANG Diane Smith for
Telephone No. (703) 308-3303

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